Results and Discussion

Regression analyses showed that survival rates were significantly correlated ($P < 0.05$) with date of collection, Delta water temperature, wind condition, and surface water condition. Other variables such as weather, specific conductance, transport time, start of collection time, day and night phase, and total catch were not significantly correlated ($P < 0.05$) with survival. PCA results indicated that one group of correlated variables consists of date of collection (time of year) and field temperature. Because fish collection started during the summer, water temperature gradually decreased as the date progressed (Figure 1). Another group consists of weather, wind, and surface water condition. As one variable got worse, so did the others. Water surface condition was significantly affected ($P < 0.05$) by wind condition (Figure 2). The first group (collection date and temperature) explained 28% of the variation in survival rate, while the second group (weather, wind and surface water condition) explained 51% of the variation.

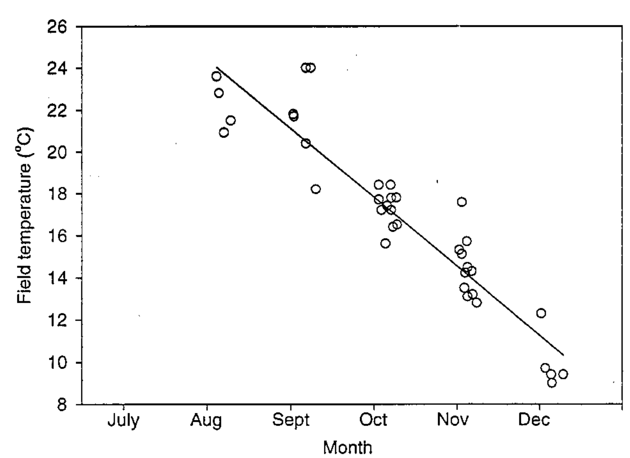

Figure 1 Delta water temperatures during the delta smelt period in 1997 and 1998

Day 1 and Day 2 survival rates increased as collection date progressed during the year (Figure 3A) and as temperature decreased (Figure 3B). Decreases in temperature decrease metabolic rate, locomotor activity, oxygen consumption, and stress-induced osmotic imbalance in fish (Reynolds and Casterlin 1980; Moyle and Cech 1996). Another reason for increased survival as date progressed may be the increase in fish size. Delta smelt rarely survive for >1 year, and smaller fish may be more sensitive to handling and transport stress.

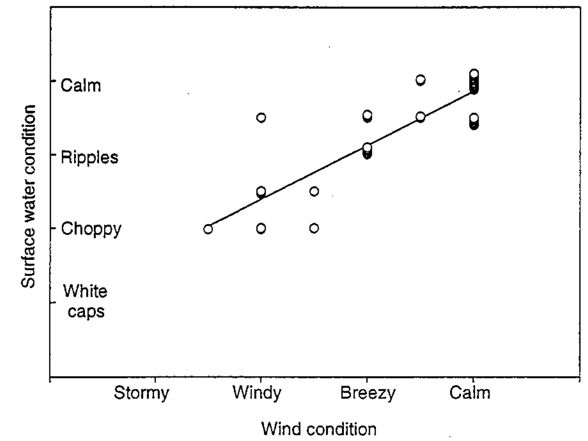

Figure 2 Relationship between surface conditions and wind conditions in the Sacramento-San Joaquin Delta. Data slightly adjusted to show overlapping symbols.

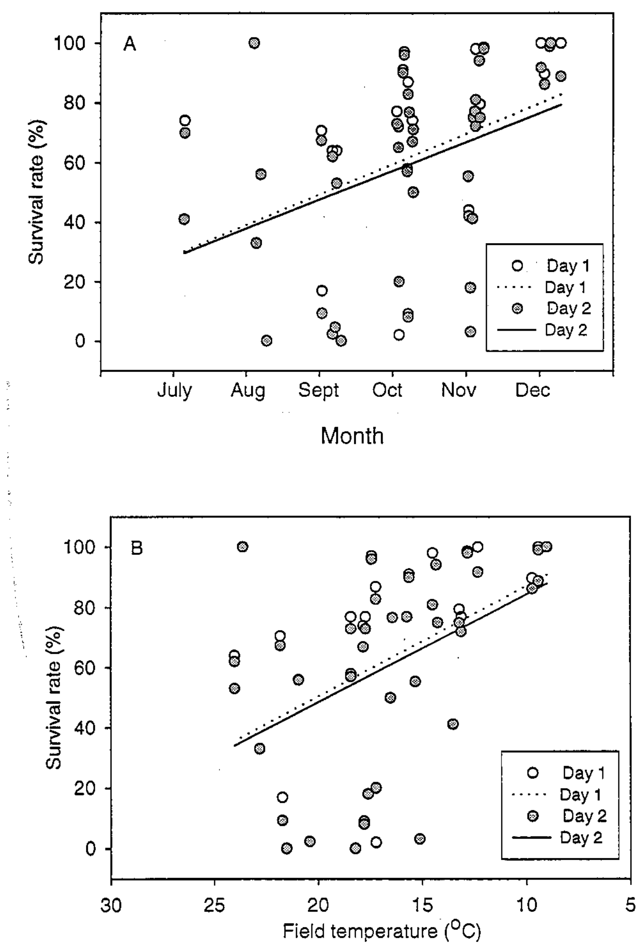

Figure 3 Delta smelt survival rates in relation to (A) time of year collected and (B) Delta water temperatures

Survival rates increased with calmer wind and surface water conditions (Figure 4). During conditions when high wind and rough surface water lurched the boat, the pursed net was often partially exposed to air. Thus, some fish were exposed to air or impinged against the net while being collected. This made the fish collection more difficult and time spent on collecting longer. After collection in rough water, the boat ride back to the dock pitched the transport containers back and forth, and sloshed the water inside the transport bags. This could result in fish striking the side of the bag and exposing the fish to turbulence. This trauma seemed to be very stressful to the delta smelt. During rough days, many fish had lost equilibrium upon arrival at the laboratory.

For increased delta smelt survival, we recommend that they be collected when wind and surface water are relatively calm and when water temperatures are <15 °C.

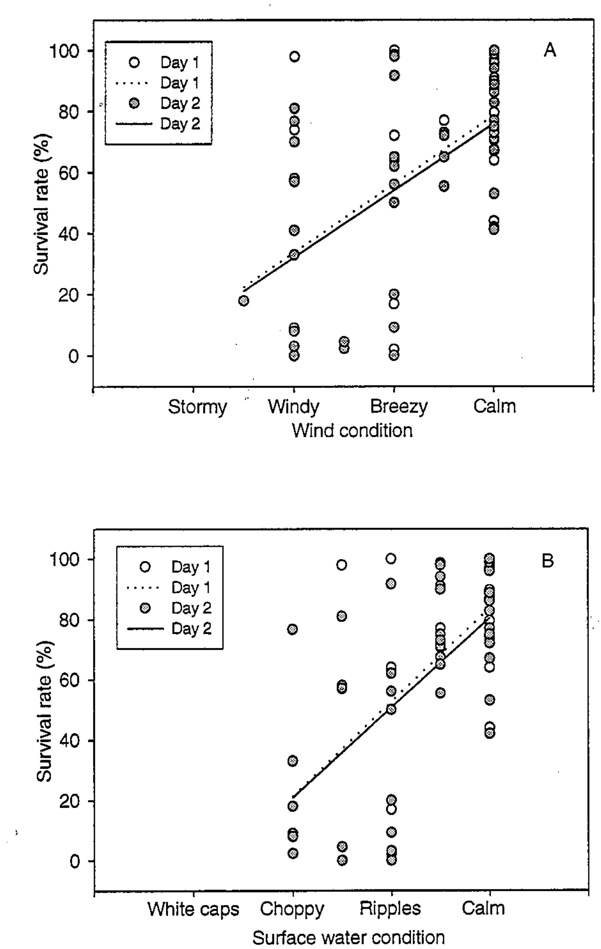

Figure 4 Delta smelt survival rates in relation to (A) wind conditions and (B) surface water conditions

Acknowledgments

We thank the Department of Water Resources for financial assistance and D. Shigematsu, R. Watanabe, R. Kurth, Z. Matica, S. Carlson, S. Gough, L. Hatton, S. Katzman, and C. Meloni for technical assistance.

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Measured Flow and Tracer-Dye Data for Spring 1997 and 1998 for the South Sacramento-San Joaquin Delta, California

Richard N. Oltmann, USGS

Introduction

During the spring of years when the flow of the San Joaquin River is less than 7,000 cubic feet per second (ft^3/s) a temporary rock barrier is installed by the California Department of Water Resources (DWR) at the head of Old River (HOR) in the south Sacramento-San Joaquin Delta to prevent out migrating salmon in the San Joaquin River from entering Old River and being drawn to the State and federal pumping facilities (Figure 1). The export rate of the pumping facilities also is reduced during these migration periods to minimize the draw of fish to the export facilities through the other channels connected to the San Joaquin River north of the HOR such as Turner Cut, Columbia Cut, and Middle River.

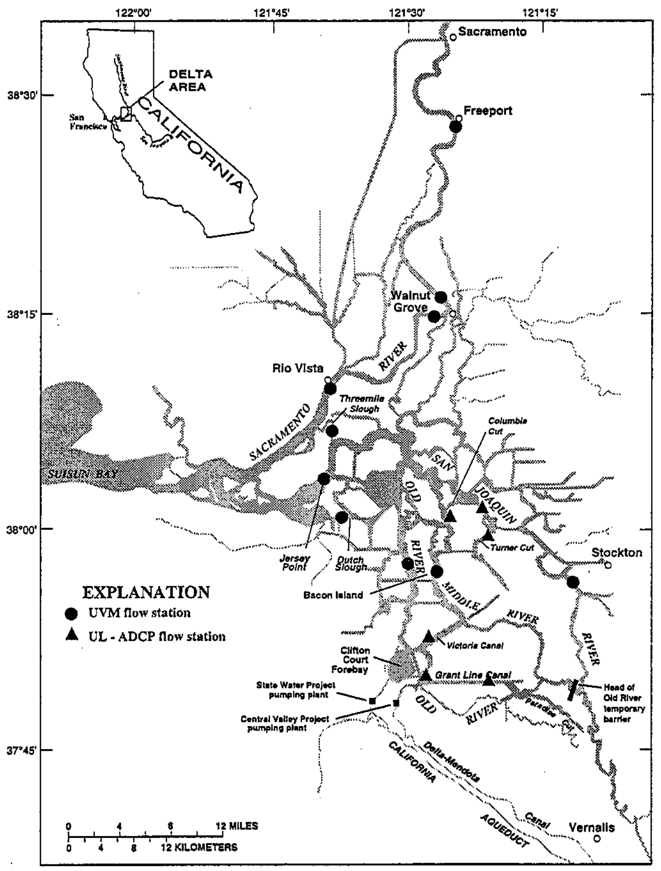

Figure 1 Map of Sacramento-San Joaquin Delta, California, showing locations of flow monitoring stations

The HOR barrier was installed during the spring of 1997 and a 30-day pulse flow was created on the San Joaquin River in an attempt to further help move the salmon to the north through the Delta and to Suisun Bay. During spring 1998, the flow of the San Joaquin River was about five times higher than during spring 1997 and much greater than 7,000 ft^3/s, thus, precluding the installation of the HOR barrier and the need to create a pulse flow.

The US Geological Survey (USGS) did hydrodynamic studies of the south Delta during spring 1997 and 1998 to (1) collect flow and tracer-dye data to assist State and federal agencies in evaluating the effectiveness of the HOR barrier and the San Joaquin River pulse flow to move salmon through the Delta, (2) to learn more about the hydrodynamics of the Delta, and in particular, the effects of the HOR barrier and the pulse flow on the hydrodynamics of the Delta, and (3) to provide flow and tracer-dye data to further calibrate flow and transport models of the Delta. This report presents and compares some of the data collected from the 1997 and 1998 flow and tracer-dye studies. A complete presentation of the 1997 data can be found in Oltmann (1998). This report does not present data on salmon movement in the Delta during the spring.

Measurement of Tidal Flows in the South Delta

Flows in Delta channels are constantly changing primarily due to the effects of ocean tides that propagate through San Francisco Bay and into the Delta. Until recently, there have been limited measured tidal-flow data available in the Delta because of the difficulties of measuring dynamic tidal flows. During the last several years, the USGS, with funding support from DWR, US Bureau of Reclamation (USBR), California State Water Resources Control Board, Contra Costa Water District, and the City of Stockton, has developed a network of ten continuous tidal-flow monitoring stations using ultrasonic velocity meters (UVM) (see Figure 1). However, only three of the ten UVM flow stations are located in the south Delta. Because the installation and maintenance of a UVM station is expensive, the USGS has been investigating less costly methods to monitor the tidal flows of the Delta. Therefore, during spring 1997, the USGS used upward-looking acoustic Doppler current profilers (UL-ADCP) in the south Delta to provide a time series of measured velocity that could be used to produce a tidal flow time series in the same manner as with a UVM.

A UVM operates by transmitting acoustic pulses across a river channel along an acoustic path that is positioned at 45° to the primary flow direction. The difference in the measured travel times back and forth across the channel provides an average velocity across the channel at the depth of the transducers and is referred to as an index velocity. To produce a time series of 15-minute interval tidal-flow data, the index velocity is converted to mean cross-sectional velocity using a velocity relation defined from numerous flow measurements made throughout the tidal flow range using a downward-looking ADCP (DL-ADCP) flow measuring system (Simpson and Oltmann 1993). Mean cross-sectional velocities then are multiplied by the corresponding channel cross-sectional area that is determined by a water-surface, elevation-channel, cross-sectional area relation developed from channel field surveys. A similar calibration approach is used when calculating flow using an UL-ADCP. An UL-ADCP is deployed on the channel bottom and measures the water velocity throughout most of the water column above the instrument. This UL-ADCP measured index velocity is then converted to flow in the same manner as described above for a UVM measured index velocity.

Spring Flow Conditions for 1997 and 1998

Figure 2A shows the flow hydrographs of the San Joaquin River at Vernalis for the 1997 and 1998 spring study periods. The flow averaged 4,060 ft^3/s for the 1997 study period and 19,220 ft^3/s for the 1998 study period. The salmon pulse flow that was created during 1997 (days 105 to 135) is evident in Figure 2A. Figure 2B shows the combined export rate of the State Water Project (SWP) and Central Valley Project (CVP). The reduced export rate associated with the 1997 pulse-flow period also is evident (days 105 to 135).

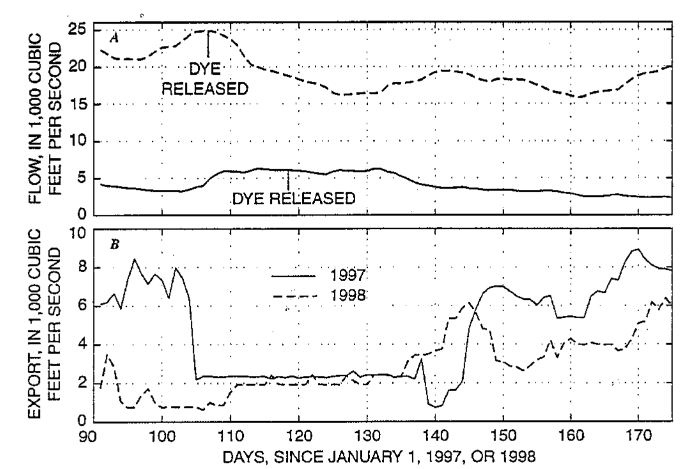

Figure 2 Daily-flow hydrographs for the spring of 1997 and 1998 for (A) the San Joaquin River at Vernalis, California and (B) the combined exports of State Water Project and Central Valley Project in the south Sacramento-San Joaquin Delta, California

The tidal-flow hydrograph for the UVM station on the San Joaquin River at Stockton (see Figure 1) for 1 April through 19 May 1997, is shown in Figure 3A. Changes in the hydrograph during the salmon pulse flow and the installation and removal of the HOR barrier can be seen in Figure 3A. The tidal flows at the Stockton station were bidirectional before the start of the installation of the HOR barrier on 9 April (day 99), but once the barrier prevented most of the San Joaquin River flow from entering Old River (the barrier contained two culverts that could pass approximately 300 ft^3/s), the flow became unidirectional, although still tidally affected. Barrier installation was completed on 16 April (day 106). The pulse flow began on 15 April (day 105) and continued until 15 May (day 135), and although flow was higher and unidirectional, it remained tidally affected. Bidirectional tidal flows did not occur again until after 15 May when the HOR barrier was breached and the pulse flow was terminated.

During spring 1998 (Figure 3B), the flows at Stockton still were tidally affected even though flow was greater than the previous spring. The peak flow that occurred on about day 106 greatly reduced the tidal flow amplitude relative to other parts of the hydrograph, but the flow magnitude was not great enough to totally suppress the effect of the tide.

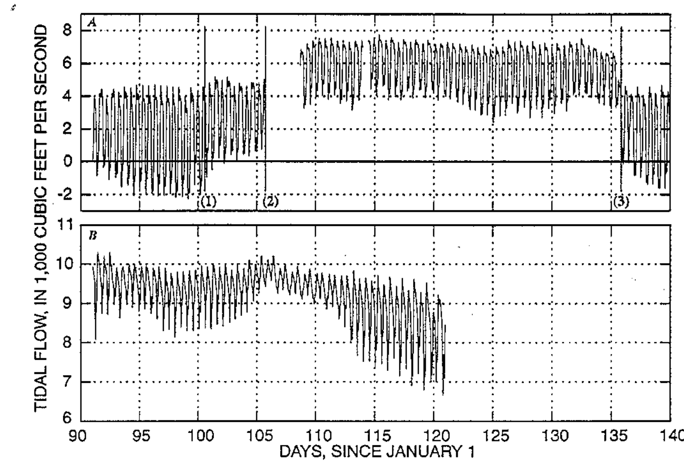

Figure 3 Tidal-flow hydrographs for (A) spring 1997 and (B) spring 1998 for the ultrasonic velocity meter station on the San Joaquin River at Stockton, California. (1) Head of Old River (HOR) temporary barrier being installed, (2) pulse flow started, (3) HOR breached and pulse flow ended.

Flow Data for Spring 1997 and 1998

UL-ADCPs were deployed at the six locations shown in Figure 1 during spring 1997 and 1998 for about three months, beginning 1 April of each year. Numerous flow measurements were made throughout the tidal range with a DL-ADCP flow measuring system at each UL-ADCP site during the deployment periods. The flow measurements were used to develop velocity relations for each of the UL-ADCP sites as described earlier. Tidal-flow hydrographs were computed for each site if index velocity data were available.

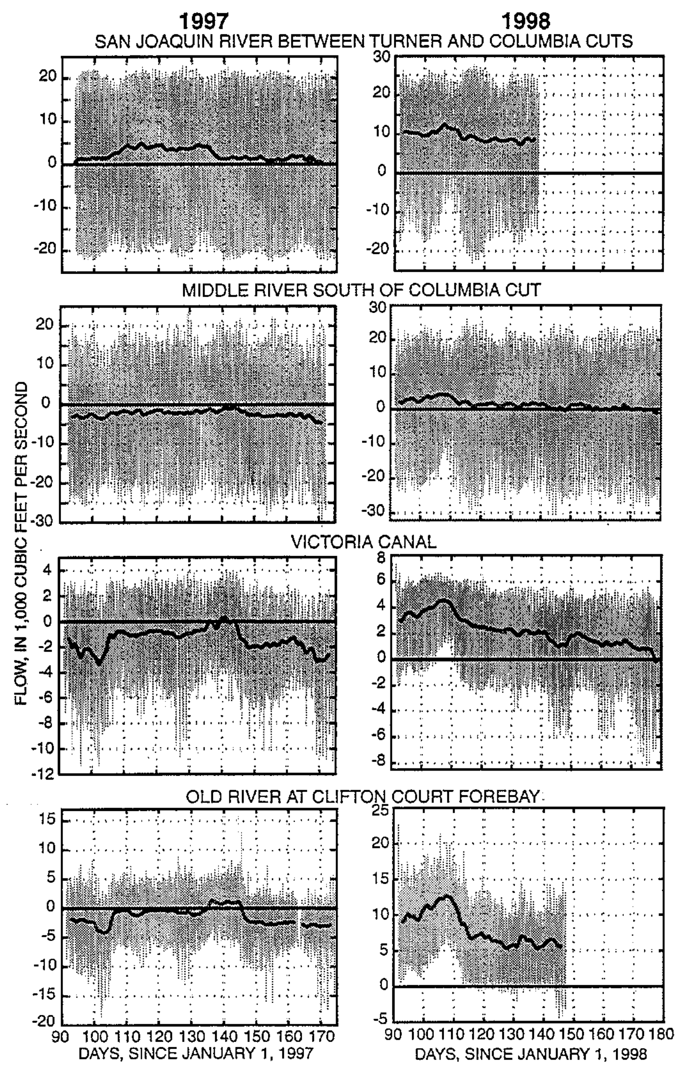

Figure 4 Tidal and net-flow (thick line) hydrographs for the spring of 1997 and 1998 for the UL-ADCP sites for the San Joaquin River between Turner and Columbia Cuts, Middle River south of Columbia Cut, Victoria Canal, and Old River at Clifton Court Forebay, California. Positive flows indicate flows to the north for the San Joaquin River, Middle River, and Old River, and northeast for Victoria Canal.

Tidal and net-flow hydrographs for 1997 and 1998 for four of the six UL-ADCP sites are shown in Figure 4. The net-flow hydrographs were generated by processing the tidal-flow data with a low-pass digital filter to remove the tidal frequencies. Hydrographs for Grant Line Canal are not shown because the UL-ADCP was disturbed (probably by a boat anchor) 17 days after the 1997 deployment and a large tree obstructed the UL-ADCP about 48 days after the 1998 deployment. Hydrographs for Turner Cut are not shown because, although a complete hydrograph was calculated for the site for 1997, no index-velocity data were collected during the 1998 deployment due to an instrument malfunction. Hydrographs for 1997 for Turner Cut and Grant Line Canal can be found in Oltmann (1998).

The dynamic nature of the tidal flows at each of the UL-ADCP sites can be seen in Figure 4. During 1997, the tidal flows were bidirectional throughout the three-month deployment period at each UL-ADCP site and the net-flow hydrographs show variations due to the 30-day pulse flow and the installation and removal of the HOR barrier. Further explanation of the effects of these manipulations of the system on the hydrodynamics of the Delta are in Oltmann (1998). The tidal flows during 1998 also generally were bidirectional at the UL-ADCP sites, despite the greater San Joaquin River flows. The San Joaquin River flow peak of 17 April (day 107) greatly reduced the magnitude of the flood flows at the San Joaquin River between Turner and Columbia Cuts and the Middle River south of Columbia Cut sites, but not enough to cause unidirectional flow as at the Victoria Canal and Old River at Clifton Court Forebay sites. The net flows were toward the export facilities for Middle River and Victoria Canal for 1997 during the relatively low San Joaquin River flow conditions and the presence of the HOR barrier, and were in the opposite direction in 1998 due to the high San Joaquin River flow conditions.

To summarize what is shown by the hydrographs in Figure 4, (1) the net flows generally are small, relative to the dynamic tidal flows, and (2) river inflow and export magnitudes can be changed, which will change the magnitude and direction of the net flows of south Delta channels, but during the periods of measurement during this study tidal effects were persistent and dominate the hydrodynamics of the Delta. It is not known what effect the change in net-flow direction has on the movement of salmon smolts through the Delta, relative to the much larger tidal flows to which the fish are continuously subjected.

Tracer-Dye Studies for Spring 1997 and 1998

Tracer-dye studies were done during spring 1997 and 1998 in conjunction with the release of coded-wire-tagged salmon smolts by the US Fish and Wildlife Service and the California Department of Fish and Game. A nontoxic tracer dye (rhodamine WT) was poured into the San Joaquin River at Mossdale (about three miles upstream from HOR) about one hour prior to the release of the salmon smolts. The purpose of the dye release was to attempt to track the movement of the water mass in which the salmon smolts were released as it moved through the Delta. The dye movement was tracked using automatic samplers that were programmed to collect half-hour or hourly water samples at nine sites in 1997 (Figure 5A) and ten sites in 1998 (Figure 5B). The water samples were retrieved daily and transported to the laboratory to be processed with a fluorometer to determine the dye concentration.

For the 1997 study, 48 L of dye were released on 28 April (day 118) during the pulse-flow period (see Figure 2A) when the San Joaquin River flow at Mossdale was about 6,200 ft^3/s and the HOR barrier was installed. For the 1998 study, 155 L of dye were released on 16 April (day 106) during the 25,000 ft^3/s peak flow (see Figure 2A) and the HOR barrier was not installed.

The first dye monitoring site on the San Joaquin River downstream of the Mossdale release point was at the Stockton UVM station (see Figure 5). The travel time for the dye concentration peak to reach the Stockton UVM monitoring site during 1997 was about 11 hours (travel rate of about 1.2 mph) compared to only about 6.5 hours (1.9 mph) during the 1998 high-flow period, which was about four times higher than during 1997.

The hydrographs shown in Figures 6 and 7 show concentration of dye as it moved north along the San Joaquin River after passing the Stockton UVM site. During 1997, some of the dye moved southwest from the San Joaquin River into Turner Cut and Columbia Cut (which leads to the Middle River monitoring site), and some of the dye moved farther north along the San Joaquin River past the San Joaquin River at Middle River monitoring site (see Figure 6). The net-flow hydrograph for Turner Cut for 1997 (not shown) showed a net flow towards the export facilities, similar to Middle River and Victoria Canal (see Figure 4). During 1997, the travel rate of the dye from the Stockton UVM monitoring site to Turner Cut (see Figure 5) was only about 0.2 mph compared with the 1.2 mph travel rate from Mossdale to Stockton. This decrease in travel rate was due to the bidirectional tidal flows about two miles downstream of the Stockton UVM site when it reaches the Port of Stockton; the San Joaquin River becomes much wider and deeper at the port, compared with the relatively narrow and shallow channel at and upstream of the UVM station.

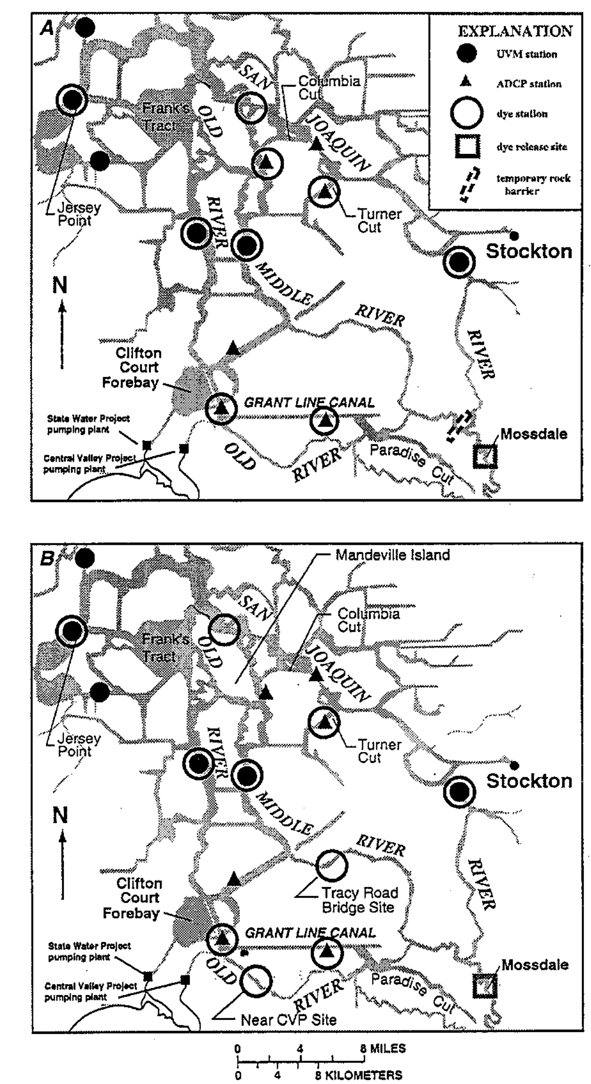

Figure 5 Locations of the tracer-dye monitoring sites for (A) spring 1997 and (B) spring 1998 in the south Sacramento-San Joaquin Delta, California. UVM, ultrasonic velocity meter; ADCP, acoustic Doppler current profiler; SWP, State Water Project; CVP, Central Valley Project.

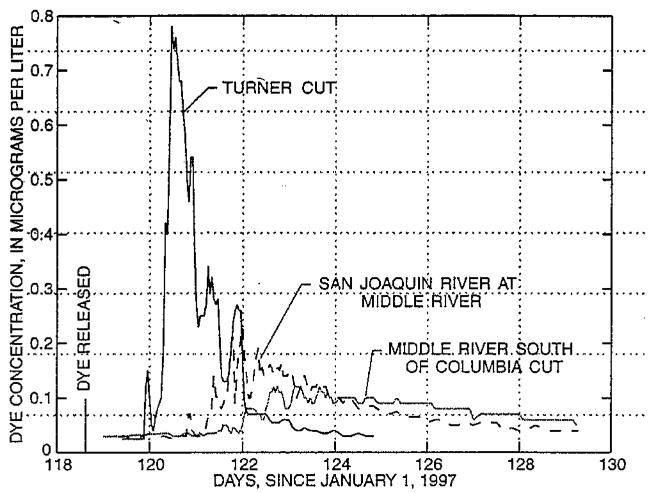

Figure 6 Tracer-dye concentration hydrographs for spring 1997 for Turner Cut, San Joaquin River at Middle River, and Middle River south of Columbia Cut, California

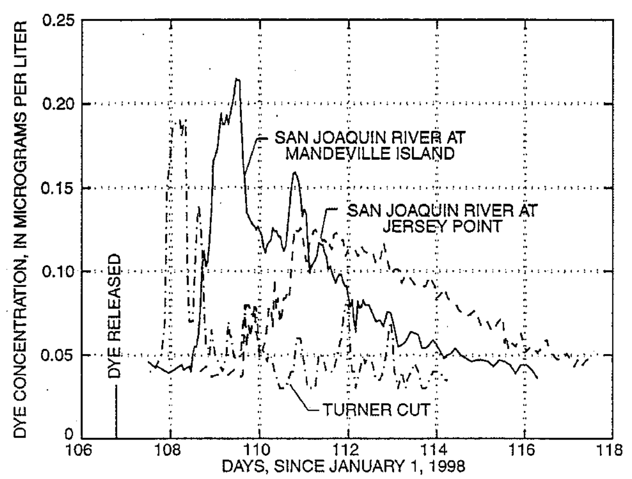

Figure 7 Tracer-dye concentration hydrographs for spring 1998 for Turner Cut, San Joaquin River at Mandeville Island, and San Joaquin River at Jersey Point, California

The peak dye concentration recorded at the San Joaquin River at Middle River monitoring site during 1997 was 0.23 micrograms per liter (μg/L) (see Figure 6), which was considerably lower than the 10.5 μg/L peak recorded at Stockton. The dye concentration peak at Stockton during 1998 was 13.8 μg/L and 0.22 μg/L (see Figure 7) at the San Joaquin River at Mandeville Island monitoring site, which is located about one mile west of the 1997 monitoring site, San Joaquin River at Middle River. The decrease in peak concentrations is associated with the sloshing of the dye with the tidal flows, and there was a gradual net movement northward along the San Joaquin River. The rapid attenuation of the peak dye concentration and the broadening of the base of the dye concentration hydrographs as the dye moved through the Delta is evident in all of the hydrographs shown in Figures 6 and 7. Whether dye was detected at the San Joaquin River at Jersey Point UVM site during 1997 is uncertain. However, a peak concentration of 0.13 μg/L (see Figure 7) was detected at Jersey Point during the 1998 study. The peak concentration occurred about four days and six hours after the dye was released at Mossdale. The time of travel of the dye peak from the Stockton UVM monitoring site to the Middle River and Mandeville monitoring sites on the San Joaquin River during 1997 and 1998 was almost identical (0.2 mph for 1997 and 0.3 mph for 1998), again, because the tidal effects dominate the hydrodynamics of the Delta relative to the San Joaquin River inflow to the Delta.

Low concentrations of dye were detected at the Grantline Canal and Old River at Clifton Court Forebay sampling sites (see Figure 5A, Figure 8) during 1997. This dye passed through the culverts in the HOR barrier and the rock barrier itself. The peak concentration at Grant Line Canal was 0.29 μg/L and occurred about three days and eight hours after the release of the dye at Mossdale. It took another three days and 16 hours for the peak to reach the Old River at Clifton Court Forebay (see Figure 5A) sampling site, which is located about six miles to the west. During 1998, however, when the HOR barrier was not installed, a dye concentration peak of 12.4 μg/L (Figure 9) was recorded at the Grant Line Canal monitoring site and it occurred about six hours after the release of the dye at Mossdale. The dye concentration peak next arrived at the Old River at Clifton Court Forebay sampling site about 4.5 hours later, and then traveled north arriving about 23 hours later at the Old River UVM sampling site. Almost all of the dye that moved through Old River passed the Old River UVM sampling site in about two days.

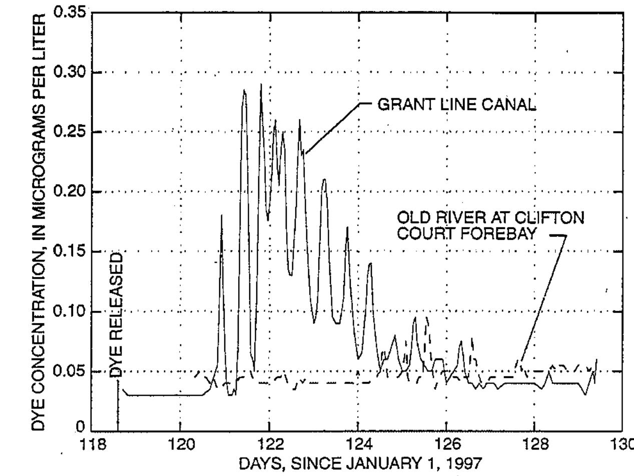

Figure 8 Tracer-dye concentration hydrographs for spring 1997 for Grant Line Canal and Old River at Clifton Court Forebay, California

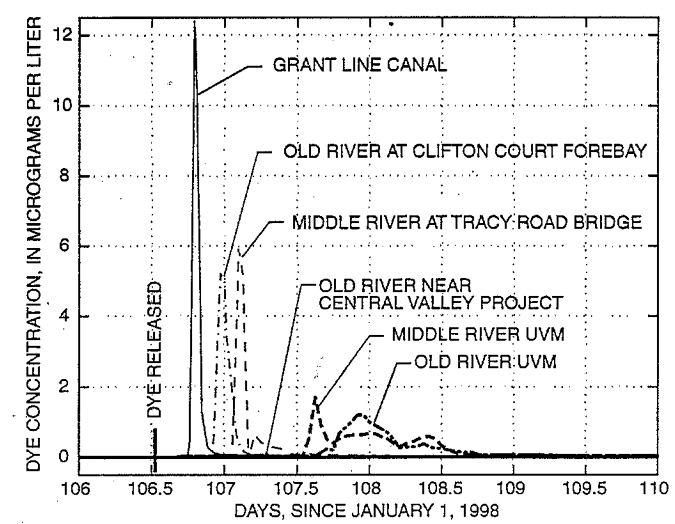

Figure 9 Tracer-dye concentration hydrographs for spring 1998 for Grant Line Canal, Old River at Clifton Court Forebay, Middle River at Tracy Road Bridge, Middle River UVM, Old River UVM, and Old River near Central Valley Project, California. UVM, ultra-sonic velocity meter.

The 1998 dye peak that went down Old River from the San Joaquin River and then into Middle River traveled at a slower rate once it entered Middle River, relative to the dye peak moving down Old River and into Grant Line Canal. It took almost 14 hours (about 1.2 mph) for the dye peak to travel from Mossdale to the Middle River at Tracy Road Bridge site (see Figures 5B and 9) compared to the 2.0 mph travel time of the peak from Mossdale to the Grant Line Canal sampling site. The Middle River dye peak reached the Middle River UVM sampling site about 12.5 hours later and then moved north to the San Joaquin River. In all likelihood, the Turner Cut dye concentration hydrograph shown in Figure 7 traveled through Middle River and entered Turner Cut from the southwest, whereas the dye entered Turner Cut from the San Joaquin River during 1997 (Oltmann 1998). Dye was detected at the Old and Middle River UVM sites during 1997, but at concentrations that were only slightly above background concentrations of about 0.04 μg/L (concentrations not shown).

Sampling problems prevented the determination of the dye concentration peak that passed the Old River near CVP sampling site during 1998 (see Figure 5B). However, data that were collected show that concentrations were lower than those that traveled down Grant Line Canal due to the San Joaquin River water that enters Old River from Paradise Cut (see Figure 5B). When the flow of the San Joaquin River at Vernalis is greater than about 20,000 ft^3/s, the water flows over a weir from the San Joaquin River into Paradise Cut at a location upstream of Mossdale. When the dye was released in 1998, the flow of the San Joaquin River was 25,000 ft^3/s, which resulted in some San Joaquin River water (contained no dye) entering Old River from Paradise Cut; most of this untagged water flowed west in Old River to the CVP sampling site.

To summarize the results of the two tracer-dye studies, (1) the dye quickly dispersed when subjected to bidirectional tidal flows, (2) the travel time along the San Joaquin River north of the Port of Stockton was almost identical during the spring of both years even though the magnitude of the San Joaquin River inflows were quite different, and (3) the dye moved southwest from the San Joaquin River through Turner Cut and Middle River toward the export facilities during 1997, and in the opposite direction during 1998.

Current Flow Data Collection

UL-ADCPs were again deployed during spring 1999; however, no tracer-dye studies were done. Five UL-ADCPs were deployed on 15 April 1999, and are scheduled to be retrieved during the week of 12 July 1999. Two of the UL-ADCPs were again deployed at the locations used during 1997 and 1998 (Turner Cut and Middle River), and at three new sites (False River, Old River at San Joaquin River at Webb Tract, and Connection

Slough). San Joaquin River flows were again high, precluding the installation of the HOR barrier.

Acknowledgments

Data collection was a cooperatively funded effort by DWR and USGS. The collection of flow and tracer-dye data would not have been possible without the funding provided by two federal programs: (1) the Ecosystem Initiative Program, which was used to purchase several of the UL-ADCPs, and (2) the Drinking Water Initiative Program. The USGS thanks USBR and DWR for providing personnel to assist with the 1998 study (Angelo Garcia, DWR, and Sylvia Reynoso, USBR) in addition to providing the tracer dye for the 1998 study. The USBR also graciously provided laboratory space during both of the tracer-dye studies. I thank Ralph Cheng, Jeffrey Gartner, and Timothy Rowe of the USGS and Geoff Schladow of UC Davis for the loan of field equipment. I gratefully acknowledge the assistance of the following USGS personnel: James DeRose, Richard Adorador, Jon Burau, Jay Cuetara, Melissa Carlozzi, Sylvia Stork, and Michael Simpson; without their efforts, this article would not have been possible.

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DSM2 1997 Dye Simulation

Tara Smith, DWR

Introduction

As mentioned in the previous article, on 28 April 1997, the US Geological Survey (USGS) released 48 L of dye from the Mossdale railroad bridge over the San Joaquin River. Eight water quality samplers, located at eight different sites in the south Delta, were used to track the movement of dye. This dye release was simulated using the Delta Simulation Model 2 (DSM2) and the results, comparing computed to observed, are presented in this article.

Description

The simulation was conducted using the quality portion of DSM2 1997 hydrodynamics validation, which can be found at wwwdelmod/docs/dsm2/calval/valid.html. During the time frame of the study, the Old River at Head barrier was in place. It contained two culverts with a capacity of passing approximately 300 ft^3/s. Forty-eight liters of tracer, over a 15-minute period, were released into the San Joaquin River at the DSM2 grid location corresponding to the Mossdale site. The dye concentration observed at eight locations was compared to model results at the same sites (Figure 1).

Results and Discussion

Figures 2 through 4 show a few of the concentration plots. From these graphs, travel time, dispersion, and concentrations were analyzed for each observation site. Following are some general comments comparing the model's results to observed data shown in Figure 1.

There was a strong match between the travel time of the simulated tracer and the observed data. The timing of the peaks between observed and computed were within a couple of hours. (This is excluding the Old River at CC Ferry site which did not have accurate observed data.)

This study was particularly helpful in showing how well DSM2 models dispersion in various areas of the Delta. The quality portion of DSM2 is calibrated using

salinity. Since there are several continuous sources of salinity, it is impossible to determine the local dispersion effects. Examining the plots show that in some areas of the Delta, such as the Stockton site, the model had greater dispersion. At other sites, like Turner Cut or at San Joaquin at Mandeville (not shown), model dispersion was less.

Difference in concentrations between the model and observed data, are a result of differences in channel velocities, flow splits, or dispersion. Additionally, the USGS considers concentrations below 0.04 g/L as background concentrations.

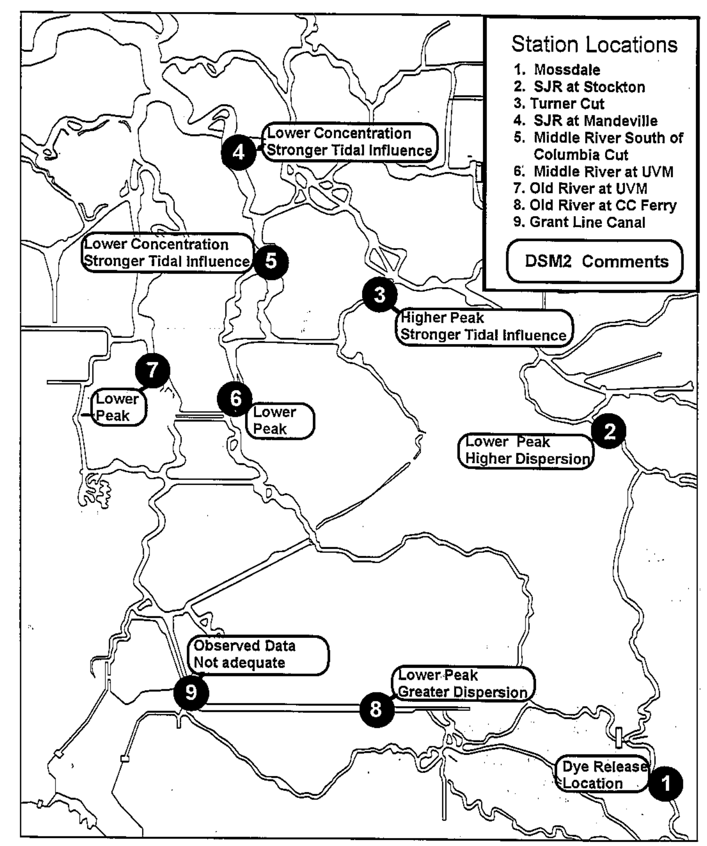

Figure 1 Sacramento-San Joaquin Delta dye measurement sites from April through May 1997

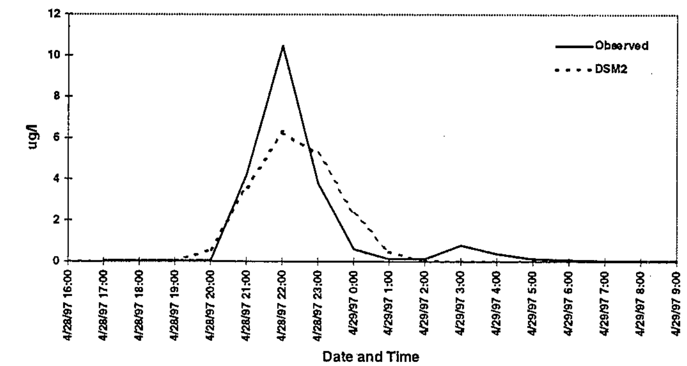

Figure 2 Observed vs. DSM2 dye concentration at the San Joaquin River at Stockton

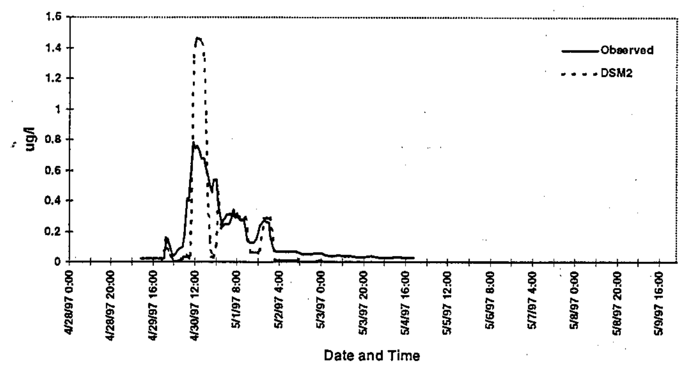

Figure 3 Observed vs. DSM2 dye concentration at Turner Cut

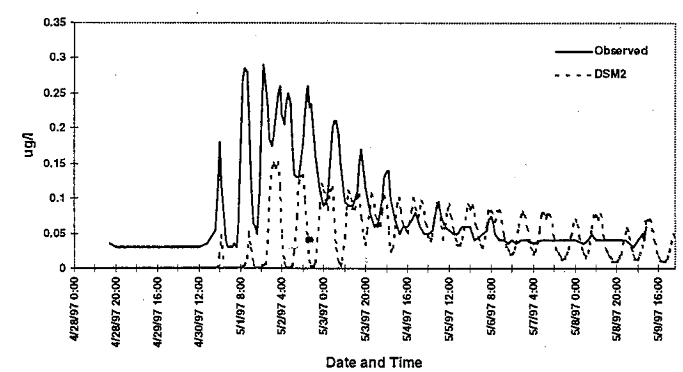

Figure 4 Observed vs. DSM2 dye concentration at Grant Line Canal